University of Southern Queensland
Faculty of Engineering & Surveying

Remote Access of Automated Test Equipment

A dissertation submitted by

Nathan John Hetherington

in fulfillment of the requirements of

ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Computer Systems) &
Bachelor of Information Technology (Applied Computer Science)

Submitted: October,2004

Abstract

The control of Programmable Instruments using the GPIB, is possible through the use of Application Programmers Interface (API). This thesis investigates the possibilities of using a web server to provide remote access, to allow interactive control of the instruments in an Automated Test Equipment(ATE) rack.

Fully documented programs where developed using the lcc-win32 software development environment, and tested using an Apache web server. Programs and web pages where developed for all the instruments included in the ATE Rack.

A web server to host all the pages developed for interaction with the ATE rack was configured to provide a password controlled system. But due to security issues regarding the PC that the equipment is attached to, connection to the Internet was not possible. But some tests where performed to simulate the various components that the Internet is comprised of, to detect possible errors that may occur.

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Acknowledgements

The assistance received by continuous meeting with one of my supervisor David Parsons through the duration of the project, aiding in the various aspects of the ATE equipment and the direction of this project. Also for acquiring and passing on of information relevant to this project.

The assistance received by supervisor John Leis with regards to the different aspect of this project and possible solutions.

The assistance received by laboratory technician Terry , who helped with gaining access to the ATE equipment and assistance when problems where encountered.

My partner Rebecca who tolerated me through this stressful time, and got me coffee.

Contents

1 Introduction **1**

2 IEEE 488 General Purpose Interface Bus **3**

2.1 History of IEEE 488 Standard 3

2.2 Type of IEEE 488 Cards Available 4

2.3 IEEE 488 Connector and Wire Configuration 5

2.3.1 Data Bus 6

2.3.2 Transfer Bus 6

2.3.3 Management Bus 7

2.4 IEEE 488 Connection Details 7

3 Application Programmers Interface Libraries **11**

3.1 Standard Instrument Control Library 11

3.1.1 SICL Commands 12

3.2 Virtual Instrument Standard Architecture 14

4 Remote Access Implementation Method **17**

4.1 Project Background 17

4.2 Project Implementation Outline 18

5 Writing C Programs **21**

5.1 Data Types and Structures 22

5.1.1 Basic Data Types 22

5.1.2 Data Arrays . . . 25
5.1.3 Structures . . . 26
5.2 Variable Scope . . . 27
5.3 Input/Output in C . . . 28
5.3.1 Standard I/O with keyboard and monitor . . . 28
5.3.2 Using files for I/O . . . 30
5.4 Functions . . . 31

6 Common Gateway Interface 33
6.1 HTML CGI Program Calling Method . . . 34
6.2 CGI Program Basic Structure . . . 34
6.2.1 Obtaining Input . . . 35
6.2.2 Processing Data . . . 36
6.2.3 Output from CGI Application . . . 37

7 Writing CGI Programs for Devices 39
7.1 Step 1: Open a Session with the Device . . . 39
7.2 Step 2: Getting Data from Input String . . . 40
7.3 Step 3: Obtain Device Commands . . . 40
7.4 Step 4: Changing Settings on the Device . . . 42
7.5 Step 5: Error Detection . . . 42
7.6 Step 6: Output Results . . . 42
7.7 Compiling Device Programs . . . 43

8 Creating Web Pages for Remote Access 45
8.1 HTML Basics . . . 45
8.2 Frames . . . 49
8.3 Creating HTML pages for ATE Instruments . . . 52

9 Setting Up an Apache Web Server 55
9.1 Installing Apache . . . 56

9.2 General Configuration 58
9.3 Configuring Server 59
9.3.1 Controlling Access 59
9.4 Adding Web Pages and CGI Programs 61

10 System Test **63**

11 Conclusion **65**
11.1 Suggested Further Development 65

A Project Specification **69**

B ASCII Character Set **71**

C GPIB Interface Cards **73**

D HTML Pages **85**
D.1 Function Generator 85
D.2 Switch Unit 86
D.3 Power Supply 87
D.4 Oscilloscope 88

E CGI Applications **91**
E.1 Basic CGI Applications 91
E.1.1 CGI get Method 91
E.1.2 CGI post Method 97
E.2 CGI Programs for Devices 100
E.2.1 Function Generator 100
E.2.2 Oscilloscope 107
E.2.3 Switch Unit 113
E.2.4 Power Supply 121

F Basic C Programs **127**

F.1 Data Types 127
F.2 Structures 128
F.3 Variable Scope 129
F.4 Input/Output Example 129

G Application Interface Library **131**
G.1 VISA Library 131
G.2 SICL Library 255

H Device Manuals **345**
H.1 Function Generator 345
H.1.1 Quick Reference 345
H.2 Oscilloscope 356
H.3 MUX 413
H.4 Power Supply 434

Chapter 1

Introduction

The objective of this project was to develop a method of providing remote access between a users computer and the devices in the Automated Test Equipment rack. This access method was to be in a manner that overcomes some of the problems with the system that was investigated previously. In completing this project the following steps had to be achieved:

1. Interface card had to be identified
2. Application Programmers Interface Libraries had to be obtained
3. Device command had to be Identified
4. Programs that Interface with device had to be written
5. Web pages for interaction with devices had to be written
6. Web server had to be installed and configured

At the moment there is no system that provides remote access to the Automated Test Equipment, this is due to limitations enforced by the Information Technology Services department of the University. The previous system never evolved further then the setup phase before these limitations where put in place for security reasons. The software that was going to be used was Hewlett Packard Virtual Engineering Environment Version 5 and was the predecessor of the software being used on the PC connected to the Test equipment. Version 5 provided remote access, but was hard to configure and required software ports left open (listening) that are not used by the standard applications permitted by firewalls.

Along with the inherited security problems that the software processed, the Windows 95 Operating system on which the software ran also created a security threat to the whole University network. And to compound the already large deficiencies of the system, it's performance was troublesome and unpredictable. Hence a need for a method that would remove the security problems and hopefully improve the reliability and performance is the foundation of this project.

The major proportion of this project is the software generated to provide the remote access. The complete code for this project is contained on the CD-ROM attached to the back of the thesis. This CD is broken it to the various stages required to implement the remote access that was produced by the project. The directories and the files that they contain are :

1. Libraries : Contains the API library files need to write a program.
2. Manuals : Contains the various device manuals that contain the commands for each device.
3. HTML_files : Contains the Web pages need to interface with the devices.
4. C_files : Contains the cgi programs source files that interface with the devices.
5. Apache : Contains the installation executable for the Apache Web Server.

Chapter 2

IEEE 488 General Purpose Interface Bus

The concept of using Automated Test Equipment for automation of test that are mundane and prone to user errors is becoming more of an widely used technique. The ability to write a program for a test sequence is becoming more attractive, as programs that provide a graphical user interfaces become available. These software packages allow the user to interact with the ATE systems via an interface card, without having to worry about the underlying system. The interface protocol that most ATE systems uses is known as the IEEE 488 standard, and has become a solid foundation for future ATE equipment to build on.

2.1 History of IEEE 488 Standard

The IEEE 488 standard was original started in the late 1960's as the Hewlett Packard Interface Bus(HPIB), this was the protocol that Hewlett Packard originally devised to connect and control devices that they manufactured. With the introduction of programmable devices the need arose for the introduction of a standard by which devices from different manufactures could interfaced was required.

In 1975 the Institute of Electrical and Electronic Engineers (IEEE) published the IEEE 488 standard that detailed the electrical, mechanical and functional specifications of the interface bus. This interface bus was specifically designed for the interaction with programmable instrumentation and was reviewed in 1978 but no major changes where made to the standard. This standard is now in world wide use by the major programmable instrumentation manufactures and known by three different names:

1. Hewlett Packard Interface Bus (HPIB)

2. General Purpose Interface Bus (GPIB)

3. IEEE 488 Bus.

Work on standard continued as the original standard did not outline the syntax and formating conventions for the communications with devices. Finally the new standard was completed and released as the IEEE 488.2, with the original standard being dubbed IEEE 488.1. This standard contained information on Codes, Formats, Protocols, and Common Commands for use with the IEEE 488 standard. The new standard did not replace the original, with most new devices supporting both, instead it provides a reasonable level of compatibility.

Finally in 1990 the IEEE 488 standard was appended to include the Standard Commands for Programmable Instrumentation (SCPI) documents. The Standard Commands for Programmable Instrumentation is the most recent attempt to provide compatibility between Programmable Instrumentation from different manufactures, this is topic of [15] . This standard defines specific commands that each instrument class must obey, if followed this will provide complete compatible and configurable systems among these instruments.

2.2 Type of IEEE 488 Cards Available

Currently on the market there are many manufactures that are producing IEEE 488.1 and 488.2 cards for interfacing with programmable instruments.Some of the major manufactures being National Instruments and Agilent Technologies Inc. Each of which are compatible with the different instrument manufactures due to the standards specifications and each with their own system drivers and API libraries.

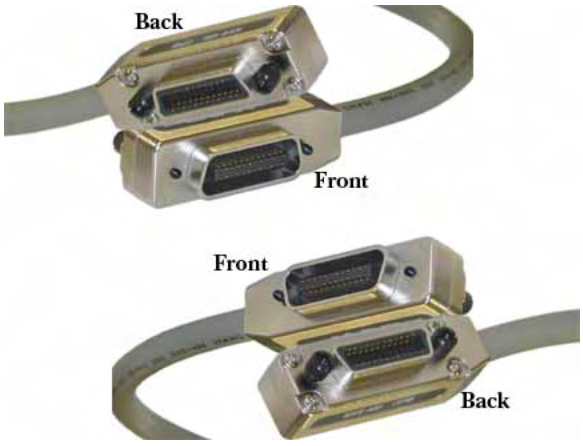
Currently there are a few different interconnection methods between the interface card and programmable Instrument. The main ones being the CN24 connector and cable that uses a 24 pin connector and cable with 24 wires, the RS232 and Universal Serial Bus(USB). The Last two connection methods are not commonly used as they are serial connections, and the ASCII characters used by the IEEE 488 standard is more suited for a Parallel transfer media such as the first method. Appendix C contains the various GPIB interface card produced by Industrial Automation Products and the card used in this project.

The speeds that the serial communication can obtain is less then that of the parallel systems, this is due to the fact that they can only send 1 bit at a time. But the distances that a serial communication link can send is usually larger and the error recovery is easier as the use of a parity bit is often sufficient to correct errors. In parallel communication if an error occurs then more then one bit may be corrupted and retransmit is required. The type of communication link required depends on environment under which the equipment will be used, but the advantages of the 24 wire connection make it the dominant method used.

2.3 IEEE 488 Connector and Wire Configuration

The type of connectors and wiring depends upon the type of interface card that is chosen to interface with the devices. In this section the original 24 wire cable and connector will be considered.The cable and connectors often refereed to as the CN24 connector due to the fact that they are comprised of 24 connector pins and 24 wires, the picture below depicts such cables and connectors:

Figure 2.1: IEEE 488 CN24 cable and connectors



As mention the cable that is usually used for GPIB interactions is a 24 wire cable, of which 8 of these wires are used for ground. The remaining 16 wires are then broken into three groups:

1. Data Bus
2. Transfer Bus

3. Management Bus

2.3.1 Data Bus

The data bus occupies 8 of the 16 signal wires, this is due to the fact that most of the devices use the ASCII character set for there interactions. The ASCII character set only requires a 7-bit number, but most computer systems use 8-bits(1 byte). The advantages of using the ASCII character is that the commands can be recognizable to humans and the data can be manipulated quite easily in programming languages. The data bus is used to transfer data, control information and address.

An example of how the devices use this is shown using the APPL: command used by the Function Generator, It contains 5 ASCII characters that can be sent via the data bus one at a time in binary. So the decimal equivalent of how this command would be sent is 65,80,80,76 and 58. The devices store the characters in a buffer then apply the command, assuming the command is a valid one.

2.3.2 Transfer Bus

The transfer bus provides a handshaking protocol that allows the system to communicate Asynchronously. It does so by allocating each of it's three wire a specific meaning, such as Not Ready for Data, Not Data Accepted and Data Available. Through the use of these control line the system can communication without conflicts and the state of the device can easily be obtain by checking the signals on these wires.

When a device wishes to transmit data on the bus, it sets the DAV line high (data not valid), and checks to see that the NRFD and NDAC lines are both low, and then it puts the data on the data lines. When all the devices that can receive the data are ready, each releases its NRFD (not ready for data) line. Then when the last receiver releases NRFD, and it goes high, the interface takes DAV low indicating that valid data is now on the bus. In response each receiver takes NRFD low again to indicate it is busy and releases NDAC (not data accepted) when it has received the data. When the last receiver has accepted the data, NDAC will go high and the device can set DAV high again to transmit the next byte of data.

This form of handshaking communication allows the devices to transmit at their own pace and provides error detection through the use if the NDAC(not data accepted) line. If any device fails to perform it's part of the handshaking and releases NRFD or NDAC lines then data cannot be sent, this will eventually result in a timeout error.

2.3.3 Management Bus

There are 5 wire allocated to manage the flow of data bytes across the interface and control amongst the various devices connected on the one bus.

The ATN (Attention) signal is asserted by the Interface Card to indicate that it is placing an address or control byte on the data bus. ATN is released to allow the assigned device to place status or data on the data bus. The interface card regains control by reasserting ATN, this is normally done synchronously with the handshake to avoid confusion between control and data bytes.

The EOI (End or Identify) signal has two uses. A device may apply a signal on the EOI line simultaneously with the last byte of data to signal the end-of-data. The interface card can assert EOI along with ATN to initiate a parallel poll. Although many devices do not use parallel poll, all devices should use EOI to end transfers (many currently available devices do not).

The IFC (Interface Clear) signal is set high only by the System Controller in order to initialize all device interfaces to a known state. After releasing IFC, the System Controller is the Active Controller.

The REN (Remote Enable) signal is asserted only by the System Controller. Its assertion does not place devices into remote control mode; REN only enables a device to go into remote mode when addressed to listen. When in remote mode, a device will ignore its local front panel controls until the local button is press on that device.

The SRQ (Service Request) line is like an interrupt: it may be asserted by any device to request the interface card to take some action. The interface card must determine which device is signaling SRQ by conducting a serial poll. The requesting device releases SRQ when it is polled.

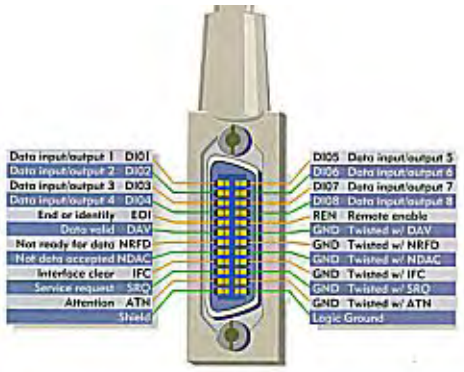
2.4 IEEE 488 Connection Details

Through the use of the Transfer and Management Bus the IEEE 488 standard is able to have up to 15 devices connected simultaneously, with each device being assigned a unique Primary address ranging from 0-30. This is similar to the way that Ethernet works, the data is broadcast to all devices and the device uses the addressing information to determine if the data was intended for them. A secondary address may also be assigned to each device, also ranging from 0 to 30, but this address is optional and is usually not

assigned.

The cables that link the devices is a shielded 24-wire cable, and the distances allowed by the standard is either 20 meters or 2 times the number of instrument connected to the bus, whichever is smaller. The speeds that are achieved by the GPIB standard are in the range of 250 Kbytes/sec to 1MBytes/sec, note it is in Bytes/sec due to the fact that the 8 data bus line. When considering the operating speed of the interface bus the cable size must be taken into consideration, if high speeds are desired the the length on cables used to connect the devices and interface card must be small.
The pin allocation is depicted in the following diagram:

Figure 2.2: IEEE 488 CN24 Connector Pin Configuration



From the diagram and Green[5] it can be seen that the 16 signal wires are broken down as follows :

Data Bus:

DI01 - DI08	Data bus	}	

Management Bus:

		}	Ten
REN	Remote Enable	}	Synchronous
EOI	End or Identify	}	Signals
ATN	Attention	#	

IFC	Interface Clear	#	
SRQ	Service Request	#	Six
Transfer Bus			Asynchronous
NRFD	Not Ready For Data	#	Signals
NDAC	Not Data Accept	#	Twisted Pairs
DAV	Data Available	#	

This shows how the IEEE 488 standard handles the transfer of both synchronous and asynchronous data.

Chapter 3

Application Programmers Interface Libraries

An Application Program Interface as defined by (www.whatis.com,2004) is the specific method prescribed by a computer operating system or by an application program by which a programmer writing an application program can make requests of the operating system or another application. In the case of this project the desired API is for the GPIB card, so that programs can be written to interface with the programmable instruments via the GPIB interface card.

After some researching on the topic of an API for the GPIB interface card contained in the system that the remote access is to be implemented, the manufactures of the card Agilent Technologies Inc provide the API for download as part of a drivers suit. Contained with the drivers which are necessary for correct operation of the card, are two API's. Which where the Standard Instrument Control Libraries and the Virtual Instrument Standard Architecture, and these will be discussed further in the following sections.

3.1 Standard Instrument Control Library

The Standard Instrument Control Library is a modular instrument communications library that works with a variety of computer architectures, I/O interfaces and operating systems according to [14]. This Library allows programs to be written in C/C++ or Visual Basic that can interface with a GPIB card. One of the advantages as stated in [14] is that programs written using this library can be ported at the source code level from one system to another without, or with very few changes.

One down fall of the SICL library is that they are Hewlett Packard dependent, meaning that they can only be used in conjunction with Hewlett Packard hardware. Although it is limiting, the advantage is that the library is efficient,reliable and easy to use with HP hardware. Also the library can be used to communicate over the different interface methods used for programmable instrument communications such as HPIB,GPIB,RS-232 and USB. This library contains a 32-bit and a 16-bit version for windows, which is an advantage as the system connected to the ATE rack is running the Windows©95 operating system which is a 16-bit OS. The SICL library was the only one that worked on the equipment in question for this project, so all programs written will use this library.

3.1.1 SICL Commands

The reader is referred to [14] for a more detailed explanation of the commands and specifics of developing applications using the SICL library, But a brief overview of some of the important aspect of the library will be discussed in the following sections. The concepts discussed in this section are Instrument independent and will be used for the development on CGI programs in a later section. There are a few example programs within [14] so these programs will be referred to rather than new example.

The first thing that an application has to do before it can interface with a device, is create what is known as a device session which creates an ID by which the application can identify the device it is talking too. As mentioned in the IEEE 488 standard each device is given a unique address(see Table 7.1), this address in what is used by the SICL library when communicating with a device. Also when the drivers for the GPIB card are setup, the interface card is given a unique name so that more one interface card can be in the one system at a time, each can be identified by it unique name. The way a session is open is similar to the way that C opens a file and is displayed by the following code:

$$id = iopen(\text{"}hpib7,9\text{"})$$

From the line of code above it can be seen that the *iopen* function is used open a session with a device. It only requires the one argument which is a string that identifies the interface card *hpib7* and the address of the device on that interface *9*. If the function is successful then a variable of type INST will be returned and stored in the id variable and will return 0 if it fails, INST is a user defined data type that is de-

fined by the library. This id will be used by the functions that read and write to the devices.

After a session is created then the *iprintf* and *ipromptf* functions can be used to communicate with the device. The strings that these functions use are ASCII characters, and are dependent on the device with which the interaction are with. The use of these two functions are :

iprintf(id,"APPL:%s:%s\n",wave_type,VtoV_Peek)
iscanf(id,"%t",buff)
*iprompt(id,"*IDN?\n","%t",buff)*

The *iprintf* function can be used with two or three arguments, and follows a similar format to the *fprintf* function for C. The first argument is compulsory as it contains the device's identity that is used in the communication. The second argument is the string that is sent to the device, this string can be a constant string or composed of string variable as long as it follows the format that the device expects. If the second argument contains variable then a third argument must be used and is the list of variable names that correspond to the format identifiers contained in the string.

The *iscanf* function is the similar to the C *scanf* function, except for the addition of the session identifier. The function will read the data on the GPIB and will store it in the variable passed to it, the %t format string specifies that an ASCII string will be read back. The *iprompt* function prompts the device with the string specified and then stores the response from the device in the variable in the fourth argument. The same sequence of events could be achieved by using the *iprintf* followed by a *iscanf*, but this function makes the process neat with only one line required.

Finally after all interactions with the device have been completed then the device session must be close, just like a file in C. This is done using the iclose method passing the session id as it's argument like follows:

iclose(id)

For the purpose of assisting in the writing of reliable code the library provides two functions to add in error detection and correction. The first of which is *ioerror* which installs a default error handling routine which is called if any of the SICL functions result in an error. The second of which is *itimeout* which allows the programmer to specify a time(in milliseconds) that SICL will wait for a response from a device. When incorporated into applications the programmer can detect errors and take action to minimize or fix

such errors.

3.2 Virtual Instrument Standard Architecture

The VISA library is similar to SICL, except they where developed with compatibility in mind, allowing the library to be used on any manufactures hardware. Agilent Virtual Instrument Software Architecture (VISA) is an IO library designed according to the VXIplug&play System Alliance that allows software developed from different vendors to run on the same system as stated in [19].

As with SICL, the VISA must create a device session before any communications between the interface card and programmable instrument can take place. The way that this is done is different then the SICL as two commands are need to create a session. These commands are :

viOpenDefaultRM(&defaultRM);
viOpen(defaultRM, "GPIB0::22::INSTR", VI_NULL, VI_NULL, &vi);

With the VISA driver a session with the default resource manager must be created before a session with a device. This is due to the fact that VISA is an object-oriented system and the word 'resource' more specifically refers to a particular implementation (or instance in object-oriented terms) of a Resource Class. The resource manager is what maintains all of the class instances, so the class that is about to be create must be registered with it. This class is then linked to the device, this section is similar to SICL. The interface card is identity and the address of the device are specified via a string. The next two arguments are VI_NULL which means "Do not return the number of bytes transferred", these are constants defined in the VISA library which alter the operation of the VISA functions. Finally the last argument is the address of a session variable and is exactly the same as the ID variable in the SICL library, it is used by the I/O functions to determine what devices they are talking too.

The Input and output functions of the VISA library works exactly the same as in SICL. These functions are *viPrintf* and *viScanf* and their arguments are exactly the same as the previously explained *iprintf* and *iscanf*, each requiring a session id, a string and the name of any variables that are being used in the string. The following shows their operation:

```
viPrintf(vi,"*IDN?\n");
viScanf(vi, "%t", buf);
```

Closing the session after all the interactions have taken place is performed via the *viClose* command with the session id being passed to it as it's argument. The VISA library has a large range of error detection functions and are explained in full in [19] and user are referred to this manual if more information is desired.

Chapter 4

Remote Access Implementation Method

With the advances in modern communication systems the potential to provide remote access to application is becoming easier. The Internet has spawned an enormous following and has become a multimedia base communications network. Due to the structure of the Internet it is quite reliable and cheap and for these reasons has become an enormous success. But because it is a shared media and the number of clients cannot always be known, it's performance cannot be measured exactly.

Taking into mind the Internet's inherent advantages and disadvantages this is the media that was in mind during the creation of this project. Nearly everyone can gain access to the Internet from a vast number of locations around the world and due to it's shared nature the cost is relatively low, hence making it a perfect resource. However the shared nature that makes the Internet so appealing causes a problem, security. This problem has manifested itself recently as hackers write viruses, worms and Trojan horses that gain access to systems thought to be secure, causing the need for protection.

4.1 Project Background

Some of the issues mentioned above are the exact reason that the previous attempts to provide remote access to the ATE racks failed. The problem in this case was that the software HP-VEE V5.0 that was being used to provide the remote access created a security hole in the Universities firewall. The way that the software operated required

that a software port be left open so the server could listen on this port for any attempts to connect. Hence for correct operation this required that the Firewall did not block this port. As stated by [2] having any open ports exposes you to potential attacks that might exploit known or yet-unknown vulnerabilities, this page also contains links to sites the help identify open ports.

The vulnerabilities that [2] is talking about are those that exist either in the Operating system itself, or Trojan horses that have found their way onto the system. In the case of the system that the HP-VEE software was installed on, the Windows©95 operating system is being used. This operating system was designed when networking and the Internet where not very popular, so the concept of security was over looked or undermined. So as well as the software leaving a port open, the OS on which it run could also jeopardize the security of the whole university network.

With this in mind one way around the firewall would be to use an application that uses a port that is allowed by the firewall. That is exactly why for this project the web server based system was chosen as this application uses port 80 (HTTP) which is allowed by nearly all firewalls. Also most web servers have the ability to specify the files that can be access by a user and also can implement password access. The implementation is similar to that used by most web pages that obtain data and process it in some manner, such as a database searches that the google search engine performs.

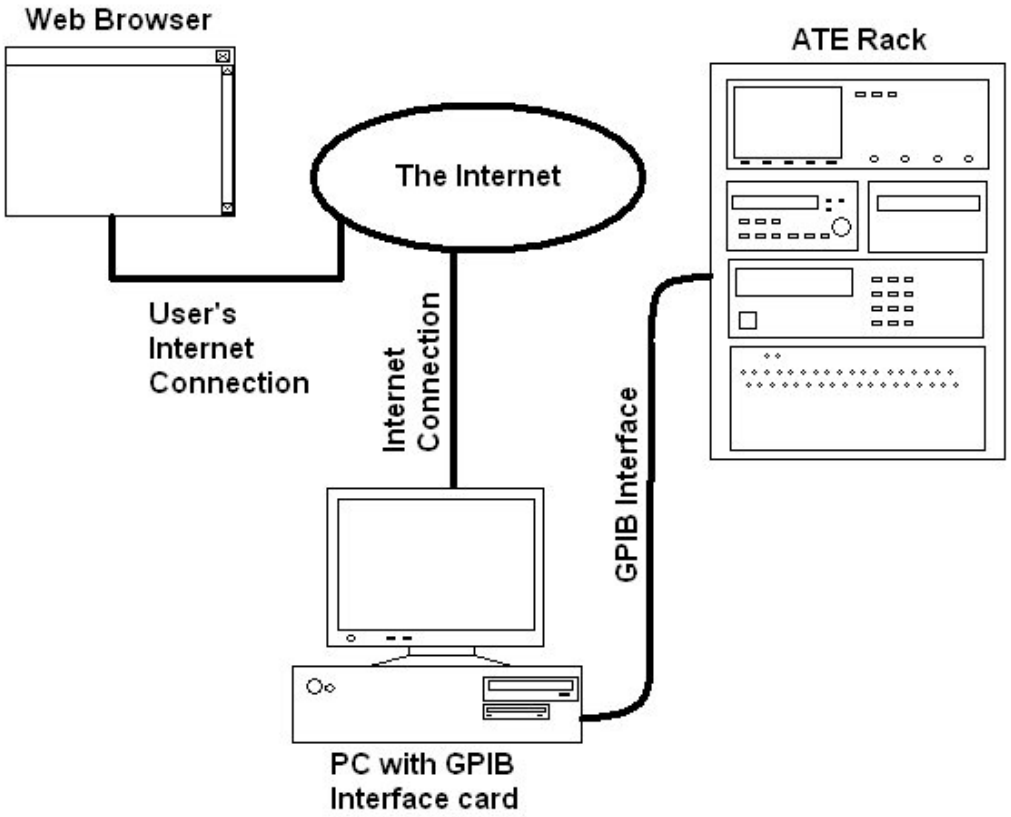
4.2 Project Implementation Outline

The concept of the way that the remote access will be implemented for the ATE rack, is the Common Gate Way Interface Method which will be discussed in detail in chapter 6. But for now the diagram below shows the basic configuration of this method:

The diagram shows the communication paths between the different elements of this implementation. At the centre of the system is the PC with a GPIB card, this system could possibly contain multiple interface cards, and is a detrimental part of the implementation. The PC is responsible for the communications between the user via the Internet and the ATE rack via the GPIB card, and is responsible for controlling and monitoring the access to the services that it provides.

The way that the PC performs these tasks is through an Apache Web Server that is installed and configured to provide the services described previously. All configuration changes can be done via configuration file and are discussed in chapter 9. The web server allows the user to access web pages for interacting with the ATE systems, and these web

Figure 4.1: Implementation of Remote Access using Web Server



pages allow the user to enter data to change settings on the programmable instrument. Once the data is retrieved by the web server, it is passed onto an application.

This application then uses this data to determine the changes to the Instrument that the user desires. The program uses the SICL API to communicate with the device and the desired setting are enforced. For the purpose of detecting problems, the device is queried and the results of this query are check against the data sent by the user. The application is then responsible for replying to the user, and must do so in the form of a HTML code. This response will be displayed to the user as a web page and will inform the user if their request was successful or not.

Because of the modular structure of this implementation, the division of devices can be done using separate web pages for each device and even for the different device sub commands. The way that this is done is up to implementor and is easily changed,

making the system easily maintainable. Each web page has one or more corresponding CGI program that is responsible for carrying out the changes on the programmable instrument that it corresponds to. If the ATE rack is upgrade or a device is replace, then it is possible to alter the system with minimal effort.

Also the addition of providing advanced features, such as sequencing, this could be done via separate web pages with their corresponding CGI program. Each page would handle one or more of the steps for the sequence. The actual way that this is implemented is entirely up to the programmer, and due to the modular structure, the separate components could be used separately or in various sequences.

Chapter 5

Writing C Programs

The first and often most important decision when undertaking a software development project is what programming language to use. Some of the criteria that must be considered, as outline in [16], these are Readability, Writability, Reliability and Cost. Each criteria must be considered in great detail as their weighting will vary for different projects, for example a real-time system will place greater importance in the reliability.

Also in conjunction with these criteria, other factors can greatly influence the decision of what programming language to use. In the case of this project, the availability of the Application Programmers Interface for a programming language played a major roll. The API for the GPIB interface card was only available for C/C++ and Visual Basic, so a decision between the two had to be made.

Visual Basic is a simple programming language that allow the user to write programs quick and easily. But as with nearly everything this advantage comes with a cost, visual basic programs can be unreliable and can be limiting in what features are provide for the programmer to use.

The C/C++ programming language on the other hand is one with a much longer history and although it is a high-level language, it also provides low-level features that the programmer can implement into there code. C/C++ are languages that are very powerful and provide the programmer with a large array of features, but can be dangerous if used incorrectly by the programmer.

Although I have had experience with both of these languages, the C/C++ programming language is the one that was chosen for this project. This is due to the fact that I have had more experience with the language and the programs compiled in C/C++

are more efficient (eg. Run faster, more reliable) than most other languages. In addition the advantage of object-oriented programming provided by C++ allows for more efficient code to be produced if desired.

The reader is referred to suitable introductory books if the fundamentals of C/C++ are not known. Suitable books include "Beginning with C" by Ron House [6] and Object-Oriented Programming in C++ by Richard Johnsonbaugh and Martin Kalin [12], however the some of the basics will be outlined in the following chapter.

5.1 Data Types and Structures

The most important structure in any programming language is the variables in which data can be stored, manipulated and retrieved. The C/C++ language has a vast variety of data types that the user can user and structures that allows the user to group variables that logically belong in one structure.

5.1.1 Basic Data Types

Within C there are a few data types and the user can define their own, each of which are used to associate the data stored with it's meaning and method of processing. A table below shows the various data types, the amount of memory they occupy and the type of data stored in them.

There are three basic data types:

1. char - ASCII characters.
2. int - Integer numbers.
3. float - Floating point numbers.
4. Pointers - Stores memory addresses.

The type of data that can be allocated to each variable is enforce by the compiler, so that unintentional assignments don't result data loss and hard to find bugs. The use can force the allocation of a variable into a different type via type casting, this is done by placing a (data_type) in front of the variable to be converted.

For example :

int_var = (int)float_var;

This will cause the floating point variable to be converted to a integer variable and assigned to int_var.

Data Types	**Num. of Bytes**	**Variable Example**
char	1	a,g,b,A,G
int	4	1,2,7,8,12
float	4	1.2,20.4,100.3

Table 5.1: Basic Data Types and Sizes

These data types can only hold a certain range of values, for integers this is -2,147,483,648 to +2,147,483,647. If this range is to short for the desired variable then a modifier, that increases or decreases the number of bytes used by the data type, can be used. There is four of these modifiers available in C/C++, these are :

1. short
2. long
3. signed
4. unsigned

The first two of these modifiers change the number of bytes allocated to the data type it is used in conjunction with. The last two deal with weather or not the most significant bit is used as the sign bit, if it is 1 the number is negative and 0 is positive.

The following table shows the ranges of variables if the modifier is used :

Data Types	Num. of Bytes	Range
short int	2	-32,768 to +32,768
unsigned short int	2	0 to +65,535
unsigned int	4	0 to +4,294,967,295
int	4	-2,147,483,648 to +2,147,483,648
long int	4	-2,147,483,648 to +2,147,483,648
signed char	1	-128 to +127
unsigned char	1	0 to +255
float	4	Increases accuracy
double	8	Increases accuracy
long double	16	Increases accuracy

Table 5.2: Effects of modifiers and data type size

The way that a variable is as follows :

int variable_name;

long int Variable_Name;

Note that the C language is case sensitive, so in the above example two separated variables will be created. The size of the variables are dependent on the system that the programs is compiled on. Because of this a method of determining the size of a data type is required, especially for dynamic memory allocation. In C the function sizeof(variable) does exactly that, it's usage is as follows:

size = sizeof(variable);

This will return an integer variable which is the number of bytes that the data type occupies. By using this function then programs can be written to perform reliably no matter what the size of the data types, especially when the program is obtaining memory dynamically. An example program is shown in Appendix C, it shows how to define various data types and the use of the sizeof function.

The final data type that C provide is the pointer, this data type is used to store memory addresses. This data type allows C programs with a very powerful tool, as it

allows for functions to access variable outside their scope and the allocation on dynamic variables. With the use of pointer the programmer is able to create abstract data types that can grow in size dynamically, which useful when the number of elements is unknown.

The basic way to define a pointer is by putting a * character directly in front of the variable name. The pointer can be of various data types so that the compile will know how many bytes there are to each variable. This is required for features such as the increment and decrement functions provided by C on pointers. The creation of a C pointer is demonstrated in the following code:

```
int *int_ptr;
int_ptr = malloc(5*sizeof(int));
```

The first line of code creates a pointer to a int type variable, at this stage the pointer is full of random garbage which happens to occupy the memory location assigned to it by the compiler. The second line user the malloc function to create a block of memory with 5 integer sized variables, note that the 5 could easily be a variable with any value. If the malloc function is successful in the creation of this memory block then the address of the first byte of the block is returned and entered into the int_ptr variable, however if malloc fails NULL is returned.

The most important thing to note here is that the variable int_ptr contains the address of the variable, hence to access the contents of the memory address the indirection operator (*) must be used. This must be placed before the variable name, similar to the way the pointer is created, then the pointer can be used just like a normal variable. This property will be shown in the following example:

```
*int_ptr = 4;
printf("The pointer contains %d \");
```

5.1.2 Data Arrays

The previous data types are only capable of holding one variable at a time. In most cases such as a string of characters are need, especially when writing programs for the GPIB as the commands to the devices are comprised of string of ASCII characters. So a way in which logically grouped data can be stored is required.

The C/C++ languages provide the user with the ability to define an array of a specific data type of any dimension. The way in which an array is created and indexed is as follows :

```
char array[10];
int intarray[10][10];
array[0]= 'h';
intarray[0][0] = 2;
```

With indexing an array in C the index range is from 0 to the size-1, so in the example above the index is 0 to 9. The second line in the example shows how a multi dimensional array is created, the indexing is the same as a single dimensional array except an index for each dimension is required.

5.1.3 Structures

In most cases it is common that different data types are required to identify an object, for example a student may have a Name, age, Student number and grade point average. So it makes sense to group this type of data into one entity, this is the purpose of C structures and C++ classes. The following code is an example of how a structure is created and defined as a new data type in C is as follows:

```
typedef Struct Student {
   int age,student_number;
   char name[30];
   float GPA;
} STUDENT;
```

After the structure is defined using the typedef function then the user can create a variable of this type in the same manner as a standard data structure. The label assigned to the data types in the string after the right parentheses and before the semi colon, in this case STUDENT. The creation of a student variable is as follows:

```
STUDENT St1;
```

After the variable has been created then each of it's elements can be access using the '.' operator. The following shows the student data type being used:

St1.age=18;
strcpy(St1,"Nathan");
printf("Age is %d \n",St1.age);

A full example program of the use of structures is found in Appendix C.2 .

5.2 Variable Scope

One of the most important considerations whenever writing C programs is the scope of a variable. The scope of a variable as defined by [16] is the range of statements in which the variable is visible. If the scope of variables is not considered then this can lead to hard to find bugs. A small sample program below displays variable scope:

```
/*********************************************************                1
* File Name: scope.c                                     *                2
*                                                        *                3
* Description: This program demonstrates the scope of    *                4
*              variables in C                            *                5
*                                                        *                6
* Written By: Nathan Hetherington                        *                7
*********************************************************/               8
#include <stdio.h>                                                        9
#include <stdlib.h>                                                       10
#include <string.h>                                                       11
                                                                          12
int x;                                                                    13
                                                                          14
// Defines sub routine                                                    15
void sub1(void){                                                          16
        int x=50;                                                         17
        printf("x is %d in Sub1\n",x);                                    18
}                                                                         19
                                                                          20
int main(void){                                                           21
                                                                          22
```

```
        x=10;                                                          23
        printf("x is %d in the main function \n",x);                   24
                                                                       25
        sub1();                                                        26
                                                                       27
        printf("x is %d after sub1\n",x);                              28
                                                                       29
        sleep(5000);                                                   30
        return 0;                                                      31
}                                                                      32
                                                                       33
                                                                       34
```

The results from running this program after it is compiled results in the following output :

x is 10 in the main function
x is 50 in Sub1
x is 10 after Sub1

From examining the output the variable x defined before the main function is seen through out the whole main function, the x variable defined in the Sub1 function is only visible to the statements in sub1. If Sub1 was meant to change the x variable, then this could lead to problems and in a program with more line could be difficult to find. This shows that create care with respects to variable scope must be taken when writing C programs.

5.3 Input/Output in C

The C programming language allows the user to read and write to what is referred to the stdin(Standard Input) and stdout(Standard Output). This standard input and output is by default the keyboard and monitor respectively, but C also allows the user to specify a file or some other I/O device. The interfacing with I/O is done via functions provided by the C standard libraries , such as stdio.h and stdlib.h, or API libraries for the I/O device such as the sicl.h and visa.h libraries for this project.

5.3.1 Standard I/O with keyboard and monitor

There are a few functions provided by the standard C libraries that read from the keyboard, their use depends on the type of data desired. Two such functions are *scanf* and *gets* , the first obtains a single variable of the type specified and the second is used to

get a string of characters. The output is handle by the one function *printf* and prints the contents of the variables passed to it, the way the variable is interpreted depends on the variable format identifier used.The following is a table of some of the format identifiers available:

Format Identifier	**Variable type**
%d %i	Decimal signed integer.
%o	Octal integer.
%x %X	Hex integer.
%u	Unsigned integer.
%c	Character.
%s	String.
%f	double.
%e %E	double.
%g %G	double.
%p	pointer.
%n	Number of characters written by this printf.

Table 5.3: Format Identifiers used with I/O functions

The *printf* function can be called to print either a constant string that the programmer hard codes in, a variable within the program or a combination of the two. The code below shows an example of each :

printf("This is a Constant String\n");
printf(" %d %f \n",int_var,float_var);
printf(" The integer variable has the value %d \n",int_var);

From the examples above we can see that the printf function requires 2 arguments. The first is the string that will be printed, this string must contain formating identifiers and control characters (\n for new line). And the second argument is the list of variable that correspond to the format identifiers. Care must be taken to ensure that the variable names are in the right order, otherwise incorrect data will be printed.

The scanf function is as follows :

scanf(%d,&int_var);

This shows that the scanf function also requires two arguments, the first tell the function what type of data is expected and the second argument is the variable that the data will be stored in. The important thing to note is the use of the ampersand operator, this operator in C means "*the address of*", and is important for the function to know the memory address of the variable.

5.3.2 Using files for I/O

C allows the user to use files for input and output and does so in a similar manner to the standard I/O functions. The only difference is that an ID for the file is needed, and is created using the *fopen()* method and after used the file must be closed using the *fclose()*. These functions are used in the following manner:

```
FILE *id;
id = fopen("Filename.txt",'r')
```

In order to read and write to files a pointer to the file must be created, this pointer is type FILE and is defined in the stdlib.h C library. Once a pointer of this type is created then the *fopen* method is used to link the file to the pointer, and it requires two arguments. The first of these arguments are the file name that is in the form of a string, this string can be hard coded in of enter by the user into a character array. The second argument is the mode the file will be opened in, and there are a few different modes that can be used when accessing a file, they are as follows:

Format Identifier	Variable type	File Created?	If File Exists?
a	Appending .	Yes	Append to
a+	Reading and appending.	Yes	Append to
r	Read only.	No	If not found returns NULL
r+	Reading and writing.	No	If not found returns NULL
w	Write only.	Yes	Overwritten
w+	Reading and writing.	Yes	Overwritten

Table 5.4: *fopen* File modes

After the file has been linked to the pointer, then the file can be written to and read from. These task are performed using the *fprintf()* and *fscanf*, which are similar to the function for standard I/O except they require file pointer. The Examples below demonstrate this:

fprintf(ID, "Number %d:\t %d\n", i+1, score[i]);
fscanf(fp, "%d", &i);

From the examples above it can be seen that their use is exactly the same as to standard I/O, except for the addition of the file pointer. All format identifiers and control sequences are exactly the same.

5.4 Functions

Within C this allow the user to write functions that perform some task and can be called by the user in a similar manner to those defined by the C libraries. The advantage of this is that the user can write a function that performs a certain task, and call it when desired instead of replicating the code each time the task is needed. The following code defines a function that multiples two numbers, of course a function may do more complex thing then this :

```
int mult(int x,int y){
   int z=0;
   z = x*y;
   return z;
}
```

From this we can see the basic structure of the a C function. This first important value is the return type of the function, this tell what data type will be returned from the function. The next is the name of the function, and can be any name as long as it does not contain any of C's special characters. Finally the last element of a function is the arguments, this is the data that is passed to the function for processing. There is no real limits on the number of arguments that a function can have, but is up to the programmer to limit this to a reasonable amount.

The main function is a special case of a function, but the same rules exist. Finally if no return type or arguments are needed then the *void* data type can be used. And the user is referred to Appendix C for sample programs.

Chapter 6

Common Gateway Interface

The Common Gateway Interface as defined by [3] is a standard for interfacing external applications with information servers, such as HTTP or Web servers. This allows the user to pass information that can be processed by the application to achieve some goal, this type of interface is used for a large variety of tasks. These task range from simple applications that query a database or process order information for On-line shopping, to more complex applications that control equipment such a space telescope or programmable electronic test equipment, the reason for this project.

When using the Common Gateway Interface, the web server allows the user to run the application locally on the server. This is the most important point, the application is not run on the user's system, it is run on the system that the web server is installed on. So because of this fact the programmer must take some precautions writing CGI programs to ensure the security of the system is preserved. As outlined in [3] this security is usually controlled by the administrator of the web server, and is performed by controlling the directories that the user can access. The CGI applications reside in their own directory, this informs the web server to execute these file rather that display them on the browser.

To ensure a more efficient and compatible system, CGI programs can be written in a variety of programming languages. The most used languages for CGI programs are C/C++, Perl and Unix Stripting Languages (BASH,KORN, etc.). If a language such as C/C++ or Visual Basic are used, then the program must be compiled and the resulting executable placed in the cgi_bin directory of the web server. In the case of scripting languages such as Perl which are interrupted languages rather then compiled, the script can be placed directly into the cgi_bin, and an interpretor will need to be installed and functioning on the system. It is worth noting that the interpreted languages will be slower than their compiled counterparts, so if efficiency is of importance then a language such of

C/C++ should be used.

6.1 HTML CGI Program Calling Method

The common way that CGI programs are integrated into web pages, is to have a button that once click causes the application to be run. The HTML code that does this must also specify the method which will be used for passing the information to the application. The code below is responsible for this :

```
<FORM METHOD="POST" ACTION="/cgi-bin/cgipost.exe">
... Code for data entry goes ...
<INPUT TYPE="submit" VALUE="Press to Submit">
</FORM>
```

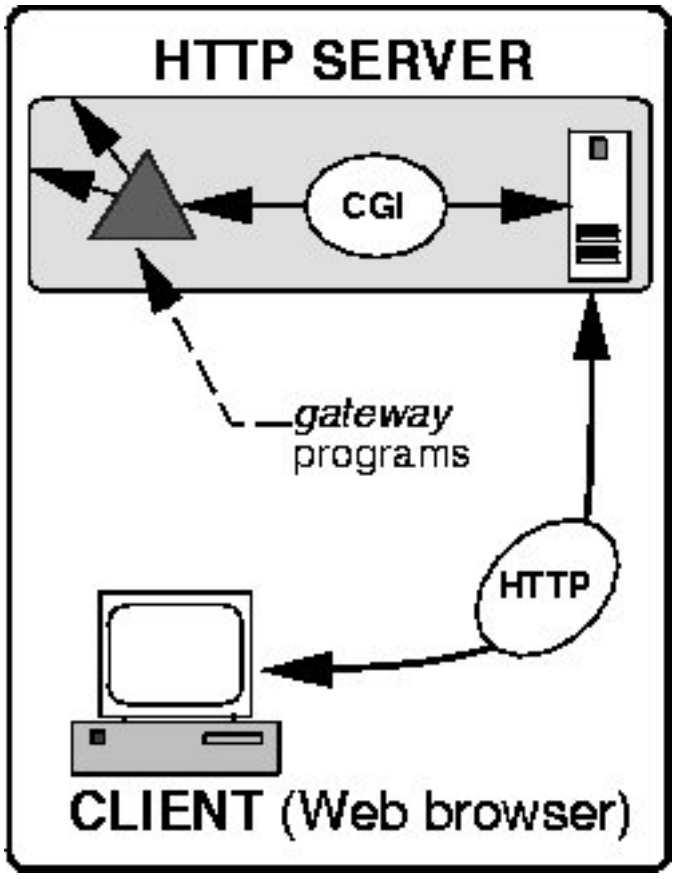
This input is pretty self explanatory, it consists of the method of input data and the application to run when the submit button is pressed. The string in the action section contains the path of the application, and is referenced from the web servers main directory. There are no limitations on the number of forms displayed on the one web page, so it is possible to have multiple submit buttons corresponding to separate applications. Caution must be taken when using multiple forms to ensure the correct application is called for each data set.

6.2 CGI Program Basic Structure

The basic operation of the CGI is shown in the following picture obtained form [4]:

From this figure, it can be see that is the Common Gateway interface is comprise of the three components mentioned in Chapter 4. This section will deal with the creation of the Gateway programs depicted in the diagram. All CGI applications will follow the same basic structure, and are comprised of three sections. These are obtaining input from the user, performing applications task and outputting a web page to user containing the status of the application. The reader is referred to Appendix E.1 which contains CGI example programs obtained from [13].

Figure 6.1: Flow of data to a gateway application



6.2.1 Obtaining Input

The main purpose of a CGI program is to obtain information from a web page, then use this information to carry out some tasks. There are two way that a CGI program can obtain data from a web page, and these are:

1. **GET** – the data are passed within the query string of the URL. For example, accessing the URL http://server.edu/stuff/cgi_program?query_string sends the data included in query_string to the HTTP server running on the machine server.edu.

2. **POST** – the data are sent as a message body that follows the request message sent by the client to the server. This is more complex than GET, but allows for more complex data. This method uses Standard I/O to pass the data to the application.

Looking at the examples in Appendix E.1 it can be seen that the get method uses environment variables to pass the data to the application. The application then reads the environment variables by using the *getenv()* function. This function requires the name of the environment variable to be obtained, and returns the contents of the contents of the environment variable specified by the argument.

The environment variable that is on interest in the get method is QUERY_STRING, this is a string that contains all the information from the web page that the application is to process. The format of this string is the same no matter weather the GET or POST method is used, and is as follows:

> TEXT_LINE_ONE=some+text&TEXT_LINE_TWO=default+value
> &TEXT_LINE_THREE=1234&PASSWORD_FIELD=secret

The sections in capital letters are the names of the input fields on the web page, the field name and value are separated by the '=' character and any white space is replaced by a '+' character. Each of the separate fields are separated using the & character, so the application must use these special characters to filter out the desired data.

The post method is much simpler to use, as the data is read from the Standard input. This is done using the following line :

> bytesRead = read(STDIN, &readBuf[0], READ_BUFLEN);

The function requires three arguments, then first specifies what input to read from and in this case is STDIN, which is defined previously as 0. The second argument is where the data read from the standard in is to be stored, the text in this argument specifies the first byte of the buffer *readBuf*. The last argument tells the function the size of the buffer, this is so it can keep track of how much more data can be placed in the buffer.

6.2.2 Processing Data

As mentioned previously the data is sent to the application as one large string, this string must first be processed and the different elements separated. After the string has been processed and it's elements are obtained and stored in different variable, then the application can use the data to perform any task desired. In the case of this project after the data has been obtained then it can be used to change the settings on the Automated Test Equipment.

6.2.3 Output from CGI Application

After the application is finished performing all the tasks it is required to, then it must respond to the user with some feedback. This response must be in the from of a HTML web page and must contain all the headers and trailers that a standard web page contains. This can be seen in the examples in Appendix E.1.1, with lines 51 to 62 of cgiget.c defining the HTML header and 262 to 264 adding the HTML trailer.

Any code can be entered between the header and trailer as long as the code follows the HTML format. The programmer can use any functions from the string.h library to manipulate the strings that will be displayed on the web page, and all information will be in the form of ASCII characters. Because the program is what is responsible for the reply, then the information that is sent back can depend on the results of the processing, making the application capable of dynamic web development. The sending of data back to the user is performed using the *printf()* within C, which prints to the standard output.

Chapter 7

Writing CGI Programs for Devices

The programs that are written for interacting with the devices of the ATE, will follow the structure outlined in the previous chapter on Common Gateway Interface. The cgi program written for the Function generator will be the eample referred to in this chapter while describing the process involved in the creation of these programs. The process described for this application is exactly the same for each device, with little variation, so can be used to create programs for the different programmable instruments available.

7.1 Step 1: Open a Session with the Device

In order to communicate with a device, the programmer must create an interface session with the device. The method to do this was outlined in chapter 3, where the *iopen()* function is used to open a session and requires the address of the device. In the CGI program for the 33120A device, the address can be defined as a constant using the #define mechanism in C.

```
#define DEVICE_ADDRESS "hpib7,10"
```

This allows the programmer to use DEVICE_ADDRESS whenever the actual device address is required, during compilation this is replaced with "hpib7,10". This is not compulsory, but makes the code easier to understand and change later. If the address of the device changes then only the definition string will need to be updated. Using this address, a session can then be opened and the resulting ID will be use when

communicating with the device. At the completion of the program this session must be closed using the *iclose* function, failing to do so will cause later run programs to act unpredictably.

Device	Address
33120A Function Generator	10
54602B Oscilloscope	7
34970A Switch Unit	9
6624A Power Supply	5

Table 7.1: Addresses of Devices in ATE Rack

7.2 Step 2: Getting Data from Input String

As mention previously the data that is enter into the fields of the web page are read into the program as one string. So the application must separate the data from this large string. The format convention of the input string is, a = is used to separate the data label and actual data and the & is used to separate the different data inputs.

So the programmer can simply step through the input string, looking for the '=' character. Once this character is located then all characters between it and the next & character is the data wanted. In the CGI programs there is a function that takes the input string as the input argument and steps through the array of characters, separating the various data. The user is referred to the CGI program for the function generator, the code for the function *getVariables(char *Buffer)*. This function will change from application to application, and it's sequencing is dictated by the sequence on the data fields on the corresponding web page.

7.3 Step 3: Obtain Device Commands

The first step in the creation of the device command is to obtain the syntax of the commands that will be sent to the device. The best source for such information is the User's Manual or Programmers Manual produced by the manufactures of the instrument. For this project, these documents where obtained from the Agilent Technologies web site.

Once the device settings being changed have been determined, then the syntax of the command to be sent to the device must be looked up in the manual. All commands are hierarchal, this means that commands have subcommands that can be used in

conjunction, to specify the exact setting of the device to be changed. One example of this is the APPLy command, that allows setting to be applied on the device, some of the sub-commands are:

:SINusoid [<frequency> [,<amplitude> [,<offset>]]]
:SQUare [<]frequency> [,<amplitude> [,<offset>]]]
:TRIangle [<frequency> [,<amplitude> [,<offset>]]]
:RAMP [<frequency> [,<amplitude> [,<offset>]]]
:NOISe [<frequency—DEF> [,<amplitude> [,<offset>]]]
:DC [<frequency—DEF> [,<amplitude—DEF> [,<offset>]]]
:USER [<frequency> [,<amplitude> [, <offset>]]]

From the above examples, the different are fields have the following meanings:

- Square brackets ([ ]) indicate optional keywords or parameters.

- Braces ({ }) enclose parameters within a command string. Default parameters are shown in bold.

- Triangle brackets (< >) indicate that you must substitute a value for the enclosed parameter.

So using the information contained above, a string can be generated to change setting can be generated. This string can then be sent to the device, and the desired changes will be made. For example the following code will set the function generator to produce a sine wave with a frequency of 12Khz, 2V peak to Peak and an offset of 0V.

APPL:SIN 12Khz 2V 0V

Note that a semi-colon is used to separate the different command levels and there is a space between the different input fields. When this string is sent to the device, a newline character must also be sent to notify the device of the end of the command. In the program written for function generator, the SIN section of this command string depends on what is selected by the user.

7.4 Step 4: Changing Settings on the Device

Using the command created using the data obtained from the user and the commands for the device, demonstrated in the previous step. The string can then be sent to the device using the *printf()* function. This is done in the following way:

iprintf(id,"APPL:SIN %s,%s, %s\n",Frequency,PtPVolts,Offset);

This is the line in the code that will actually implements the changes on the device.

7.5 Step 5: Error Detection

After the string has been sent to the device, then it must be checked that the change was actually implemented. The easiest way to check that the changes have been implemented is to query the device for it's current setting, this can then be compared to the string that was sent to the device. The devices current settings can be obtained by using the *iprompt()* function.

ipromptf(id, "APPL?\n", "%t", temp);

This will cause the current setting to be in the variable temp as a string, this can then be compared using the string compare function *strcmp()*. If the two strings are the same then strcpy will return 0, and then the appropriate action can be taken.

7.6 Step 6: Output Results

Depending on the result of the strcmp function, a result must be sent to the user to inform on the status of their request. If the settings of the device where successfully changed, then a web page stating that the settings have been applied will result. If the program fails, then the user is informed to try again. There are nothing that the user can do if the problem is with the hardware, in this case an error file is written and it is up the administrator to check this file. Later implementations may sent an e-mail to the lab technician, informing them that an error has occurred.

7.7 Compiling Device Programs

When compiling programs that make use of the SICL library, then some sets must be taken. First is the inclusion of the sicl.h header file, which contains the prototype definitions of the functions provided by the library. And finally, is informing the link which library file contains the machine code for the functions defined in the header. In the case of this project sicl32.lib was the appropriate file.

Chapter 8

Creating Web Pages for Remote Access

The Hyper Text Mark-Up Language is a plain text based language, and can be created, edited or viewed using a simple text editor on any computer platform. HTML is similar to a scripting language as the web browsers reads the HTML file and determines the way of formating the data from the code. This makes HTML multi-platform as long as a web browser exist for that platform. Also with the modular structure of the web browser, this allows for different services to be provided via plug-in. This makes the power of HTML almost unlimited.

8.1 HTML Basics

The HTML language is based on what is known as HTML tags, these are used to notify the browser of formatting method. The basic structure for all HTML tags are <HTML_TAG> to indicate the beginning of an HTML environment and </HTML_TAG> to finish the effect of this environment.

The first tag that must exist is the <HTML> tag as it tells the web browser where the HTML code begins and ends. This alone would created a valid web page and could be loaded, but the result would be a blank screen. After the beginning and end of the HTML file is defined there are two more sections that need to be created.

The first of these sections is the HEAD, this section contains information about the web page. One such element is the TITLE of the web page, the contents of this field will appear in the browsers title bar. Additionally the contents of the

TITLE field will be used for the history list of the browser and also will be the title entered when the page is book marked.The final section that a web page will consist of is the BODY, this section contains all the information that is to be displayed on the web page.

The following code will produce a simple template for a web page:

```
<HTML>
<HEAD>
<CENTER><TITLE> Simple Web Page </TITLE></CENTER>
</HEAD>
<BODY>
<H1>This is a Simple Web Page !!</H1>
</BODY>
</HTML>
```

And the resulting web page from the code above is :

Figure 8.1: Simple HTML page

From the simple template, this code can be added to to make more complex HTML pages. There are heaps of HTML tags that allow the developer to customize the appearance of the web page they are developing. Typing text into the body section of the HTML page will result in the text being displayed in the default font and size. But tags must be used to format the appearance of the text,tables, division lines and other elements.

The HTML language provides the developer with a large range of features, just like a word processor, to create format documents. The developer can insert pic-

tures,table, itemized lists and change the appearance of various elements of their page. There are such a large number of element that can be changed through the use of HTML tags, that readers are referred to introductory HTML books such as [1] or the Internet for various formatting information.

Another important feature that HTML provide is the ability to create data entry field, these are what will be used by this project to pass data to the CGI programs. There a few different types of data entry fields, but the ones of interest for this project are, the text entry field and radio buttons. The first element creates a box in which plain text can enter, the maximum size of which can be set. The next has a grouped set of options, of which only one can be selected at any time.

The tags just mentioned will be displayed by the following code and explained after the code:

```
<!-- This creates a comment >                                                    1
<HTML>                                                                          2
<HEAD>                                                                          3
<TITLE> Customized Web Page </TITLE>                                            4
</HEAD>                                                                         5
<BODY BACKGROUND="background.jpg" TEXT="#FFFFFF">                               6
<CENTER><H1>This is a Simple Web Page !!</H1></CENTER>                          7
                                                                                8
<P>This is an Itemized List:</P>                                                9
<HR>                                                                            10
<UL>                                                                            11
<LI>Item 1</LI>                                                                 12
<LI>Item 2<UL>                                                                  13
   <LI>Item 2A</LI>                                                             14
   <LI>Item 2B</LI>                                                             15
 </UL></LI>                                                                     16
<LI>Item 3</LI>                                                                 17
<LI>Item 4</LI>                                                                 18
</UL>                                                                           19
<HR>                                                                            20
                                                                                21
<P>Radio Buttons:</P>                                                           22
<input type="radio" name="group1" value="Button1" checked> Button 1<br>         23
<input type="radio" name="group1" value="Button2"> Button 2<br>                 24
<input type="radio" name="group1" value="Button3"> Button 3<br>                 25
<input type="radio" name="group1" value="Button4"> Button 4<br>                 26
                                                                                27
<HR>                                                                            28
```

```
<TABLE align="center" border="3" width="668" cellpadding="3" id="table1">
<TR>
  <TD width="222">Text 1 :
  <input type="text" name="text1" size="20">
  </TD>
  <TD width="222">Text 2 :
  <input type="text" name="text2" size="20">
  </TD>
</TR>
</TABLE>

</BODY>
</HTML>
```

This code contain only a small proportion of some of the features provided by the HTML language, but the use of options shown in the example demonstrates the convention used for HTML options. Line 6 shows how options for the body section can be used to alter the appearance of the overall page, the BACKGROUND option allow the background of the page to be set to a color or an image, the TEXT option defines the fonts color.

The use of the HR, P and BR tags show how they can be used to alter the appearance of the page. The P tag defines a paragraph, and creates the spacing before and after the text that the code encloses. The BR tag creates a line break and does not require a </BR> tag , this is the same as <HR> except a horizontal line is created across the page.

HTML provides the ability to create a list, the list will be numbered or have bullet points depending what tag encloses the list. In this case the UL tag is used and produces a bullet pointed list, if OL was used then the list would be numbered. Each element of the list enclosed within the list type are specified by the LI tag. The addition of another list type can be used to create a sub list within another list.

The radio buttons can contain an unlimited amount of elements, but only one element can be selected at any time. The group is specified using the name field, all elements with the same name will belong to a group. The value field is used to separate each of the elements of a group, this is so that the individual button can be identified. One final feature of the radio button is the ability to specify a default value, this is so that one of the group is always selected, and is done using the checked option.

Finally is the text entry field, this element allows the user to under strings that can be used by a CGI program. This element is created using the input tag, the type of input is specified using the type field and the size option specifies the number of characters that can fit in text field. Just like the radio buttons the text field has it's own unique

name, specified in the name field. The way that the text fields are displayed in the above example, uses a table structure which allows the creation of a matrix with the text fields as the elements. This structure is simple to create, with the ¡TR¿ tag used to create a matrix row and the TD tags create columns. This allow the developer to group similar fields to create some logical grouping of data.

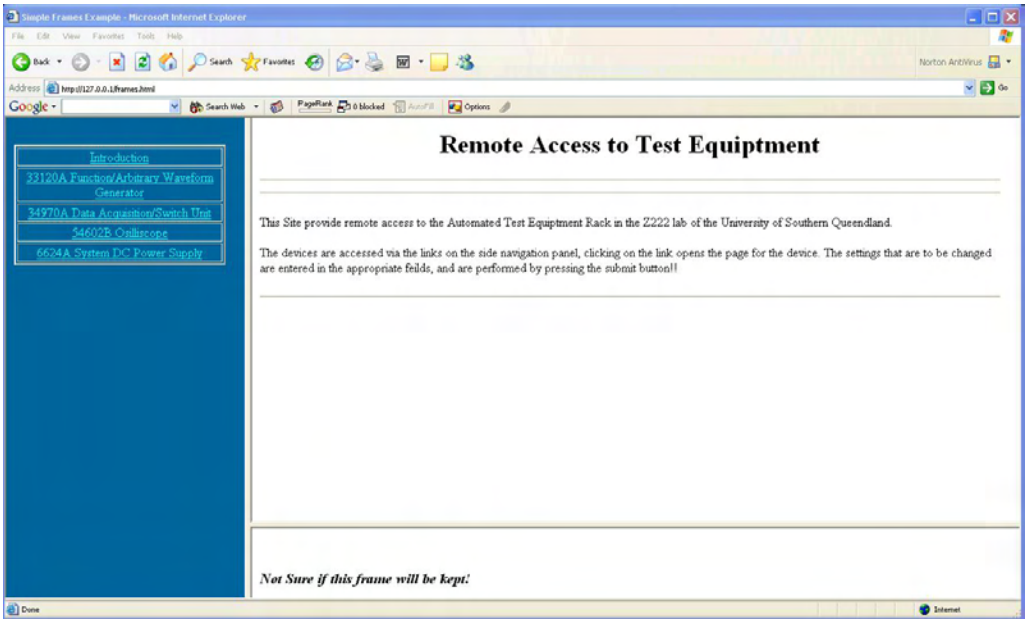
The figure below shows the page resulting from the code :

Figure 8.2: Web page with Background and other elements.

8.2 Frames

Also HTML allows the developer to create what are called frames, which allows multiple Web Pages to be displayed at one time. Using this structure the developer can use one of the HTML pages as a navigator to the other pages. This is the method used to provide access the the different programmable instruments in the ATE rack. The following figure displays the main page designed for this project, and the code after the figure shows how a form is created:

Figure 8.3: HTML Frames


Simple Frames Example - Microsoft Internet Explorer
Introduction
33120A Function/Arbitrary Waveform Generator
34970A Data Acquisition/Switch Unit
54602B Oscilloscope
6624A System DC Power Supply
Remote Access to Test Equiptment
This Site provide remote access to the Automated Test Equiptment Rack in the Z222 lab of the University of Southern Queendland.
The devices are accessed via the links on the side navigation panel, clicking on the link opens the page for the device. The settings that are to be changed are entered in the appropriate feilds, and are performed by pressing the submit button!!
Not Sure if this frame will be kept!

```
<html>                                                                  1
                                                                        2
  <head>                                                                3
  <!-- DOCTYPE HTML -->                                                 4
  <!-- A Basic HTML Frames example -->                                  5
  <!-- Nathan Hetherington 2004 -->                                     6
                                                                        7
  <title>ATE Remote Access</title>                                      8
                                                                        9
  <!-- this is for use by web search robots -->                         10
  <!-- "keywords" is used for searching -->                             11
  <!-- "description" is the summary returned -->                       12
                                                                        13
  <meta name="author" content="Nathan Hetheington">                     14
  <meta name="keywords" content="html">                                 15
```

```
<meta name="description" content="Provide remote access to ATE equiptment">          16
                                                                                    17
<!-------------------------------------------------------------------------------> 18
<!-- 150 = pixels, * = remainder --><!-- *** warning: if only a single panel *** --> 19
<!-- do not use nested frameset environment -->                                     20
<!-- 10%=percentage -->                                                             21
<!-------------------------------------------------------------------------------> 22
<!-------------------------------------------------------------------------------> 23
<!-------------------------------------------------------------------------------> 24
                                                                                    25
</head>                                                                             26
                                                                                    27
<frameset cols="300,*" border="5">                                                  28
<frame src="Frames_files/NavPanel.html" name="Nav">                                 29
<frameset rows="85%,15%">                                                           30
<frame src="Frames_files/Project.html" name="Upper">                                31
<frame src="Frames_files/Static.html" name="Lower" scrolling="no">                  32
</frameset></frameset>                                                              33
                                                                                    34
<noframes>                                                                          35
  <BODY>                                                                            36
    <P>        This document uses frames        </p>                                37
           This is in the noframes section                                          38
  </body>                                                                           39
                                                                                    40
</noframes>                                                                         41
                                                                                    42
</html>                                                                             43
```

The code for this page was obtained from [13] and altered to suit need of this desired implementation. The important section of this code is lines 28-33, as this section is responsible for the division of the page into frames. The *frameset* tag is used to specify the sections containing the information about how the page is to divided, this division can be vertically using the cols option or horizontally with the rows option. The size of the divisions are specified with the option used, and can be expressed as number of pixels or as a percentage.

After the frame sizes have been specified, the pages that must be loaded into each section must indicated. This is the purpose of lines 29,31 and 32 and various options can be applied to each frame, such as the no scrolling option that is enabled for the static frame. The division of the page and manner in which the pages operate is entirely up to the developer, and allows for the implementation of more powerful, user friendly sites.

8.3 Creating HTML pages for ATE Instruments

The creation of HTML pages is a creative process, and aspects such as appearance and operation can vary tremendously. But in the case of web pages for use with programmable instruments, there are a few aspects of the implementation that remain constant. For example the way that settings are changed is dependent on the way feature being set operates, and usually varies from device to device. Some setting of a device may be limited to a set of values, for example the wave type produced by the function generator, so for this reason radio buttons more suit the acquisition of such information.

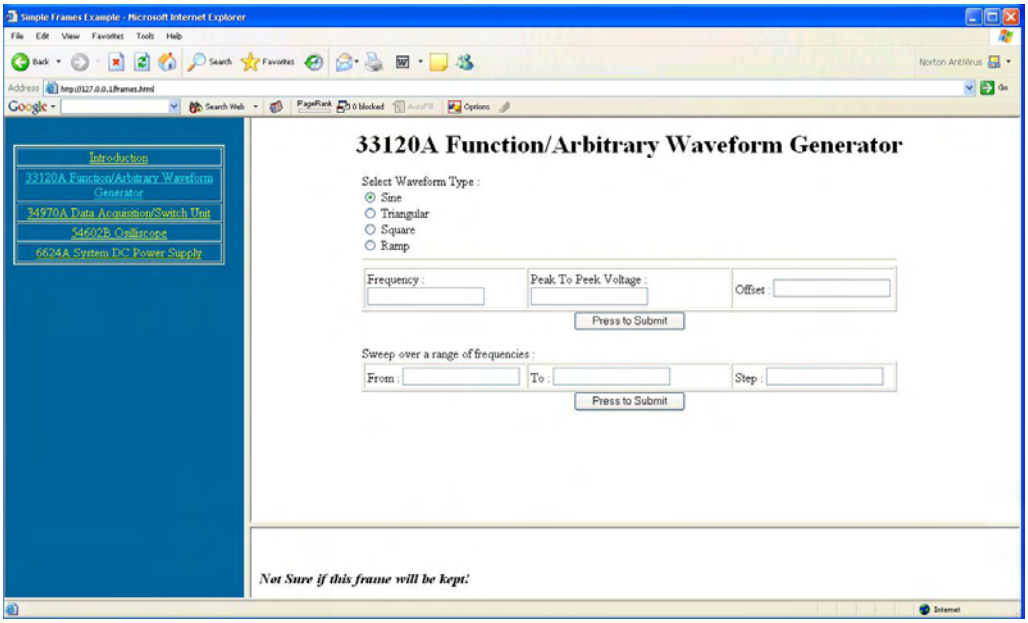
It is not totally necessary that the right input type be used, but it makes the development of CGI code easier. If a text box entry was used to acquire the wave type desired, then the CGI application would have to check that the entered wave type is valid and take action if it was not. With the use of the best suited input method, then the need to code for error detection and correction is not necessary.

So for the implementation of web pages for the devices, a simple analysis of the feature that the device provides was required. Features that only contain a discrete number of setting are more suited for implementation using radio buttons, if a continuous number of values where available then a text box should be used. The web page created for interaction with the HP 33120A Function Generator is shown in the following figure:

The function generator's web page above shows how multiple functionality can be implemented on the one page. For this web page the selection of the waveform type is done using radio buttons, this makes sense as there are only the four different waveforms that the web page will provide. The selection of frequency, peak to peak voltage and voltage offset is done using text boxes.

Creating web pages for each device allows the user to access and alter the settings of the specific device that the page was written for. But the desire to provide some form of sequencing to the user may be desired. This could be done by creating web pages for each step in the sequence, then via a navigation frame such as the one used for the main implementation above could be used to step through the steps. Providing

Figure 8.4: HP 33120A Function Generator Web Page



the sequencing in this manner would reduce the size an complexity of the CGI programs that are responsible for each step. This structure would also make it possible to use the individual components in a various number of sequences, and each step would be easily maintainable.

Alternatively the implementation of sequencing could be done via the use of a page with the individual steps all listed, with the submit button only available for the step currently available. Through the use of a complex CGI program for each step, a web page with the submit button for the next step being returned after the changes have been implemented. This manner of implementing the sequencing has the advantage of stepping the user through the step automatically, the main disadvantage of this method is the cgi cannot be used for another sequence. If a new sequence was desired then a new web page and corresponding CGI programs would need to be created.

Another aspect of creating web pages for the ATE devices, is the type and number of settings that should be implemented on each page. For some devices, such as the Power Supply, using one page to contain all the possible settings is sufficient. But in the case of other devices such as the Function Generator, Oscilloscope and MUX, there are far too many options to be included on the one page. So some form dividing the these

setting must be decided.

As mention in chapter 7, the device settings are separated into sub command and using these divisions would make sense. This type of devision would make the development of CGI programs that are responsible only for a certain sub-command, decreasing their size and complexity. Also be cause the sub-division of command is done based on the function they provide, this type of division is logical.

But there is no need to implement all the commands and sub commands, as a majority of these features many not be need or could be out of the scope of the users knowledge. So providing access to only a small group of commands is also possible, and the commands omitted could be left as their default or set to a desire value. Creating the web pages in this manner controls the type of settings that the user can use, and helps in the coding of corresponding CGI programs. The code for the pages created for this project are located in Appendix D, these page contain only basic features for each device. The other features for the devices can be implemented in a similar manner.

Chapter 9

Setting Up an Apache Web Server

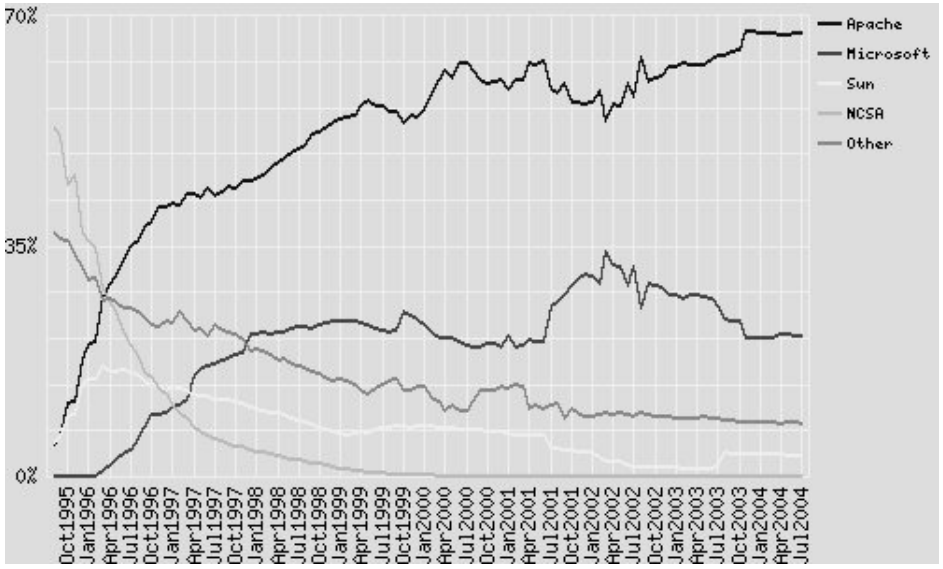
The web server used in the implementation of this system does not matter, as long as it is capable of providing the Common Gateway Interface method. There are various reasons for choosing Apache as a web server, for both this project and web hosting in general. This first is Apache's dominance in the web server domain, this is illustrated by the graph shown in the figure below. The only other web server that has a noticeable following is Microsoft's Internet Information Server, which is shipped with Windows Server operating systems.

In addition to it dominance of the market, Apache is also a cross-platform web server. This means that versions of Apache can be obtained for various operating systems, such as Microsoft Windows, Mac Os and Linux/Unix. From the view of this project this is beneficial, as the system could be implemented in another Operating System, inheriting their security and reliability advantages.

Probably the most appealing aspect of the Apache web server, is the amount of On-Line documentation and support that is available. This is due to the fact that Apache is an Open Source program, making it free to the public. And because this software is open source, this means that any software bugs and security holes are often detected and corrected much quicker then commercial products. Apache can be obtained from **www.apache.org** and is free for download in various versions and platforms. This site also contains a large amount of documentation for the installation and configuration of the apache server.

For this project an older version of apache web server was required, this is due to the fact that the system that apache was to be installed to contains the Windows 95 Operating System. Attempts to install new versions resulted in problems, mainly due to

Figure 9.1: Market Share of Various Web Servers



the fact that later versions are designed to take advantage of Thread technology. The Windows 95 OS is not a true multi-tasking OS and does not support the use of threads. Also it is worth noting that using Windows 95 for a web server is advised against, because of the security risks that the OS creates. So for further development of the process developed by this project, it is advised that a different OS is used for the system.

9.1 Installing Apache

As mentioned earlier, Apache can be downloaded from **www.apache.org** or various mirror sites and can be obtained in binary or source form. If the source code version is acquired, then it must be compiled prior to installation. The advantage of the source version is that in the compilation process, it can be optimized for optimal performance on that system. But a majority of the time the binary version is sufficient, and comes in .exe or .msi format.

There is not much difference between these two formats, except the msi files are smaller. The msi windows installer technology contains all data and instructions required to install the application on a system. In order to use a msi file then the msi.dll dynamic library must be installed, this is not necessary in later versions of Windows such as XP,2000.

For the Windows 95 operating system, the winsock libraries have to be updated

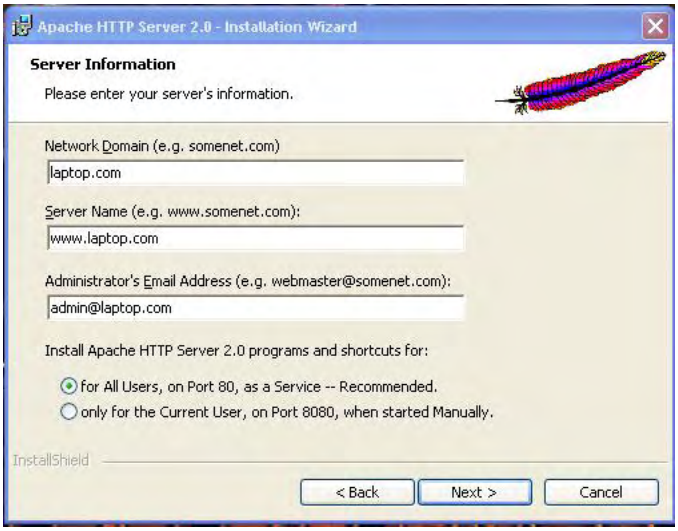
to winsock 2 before installing the apache server. The winsock libraries are what the windows OS uses for network communication, and contains functions for the creation, destruction and use of TCP communications. Web servers use TCP for their communications, which as stated in [18]:

1. Accept a TCP connection from client(a browser).
2. Get the name of the file requested.
3. Get the file (from disk).
4. Return the file to the client.
5. Release the TCP connection.

The file required to add support for msi files and update the winsock libraries are on the attached CD, or can be obtained from Microsoft's web site.

Once the desired version of the Apache web server is acquired, then simply executing the exe or msi will initiated the installation process. The installation process is pretty much self automated, except where information about the Domain and Administrators e-mail address are required. An example of this is shown in the figure 10.

Figure 9.2: Apache Installation


Apache HTTP Server 2.0 - Installation Wizard
Server Information
Please enter your server's information.
Network Domain (e.g. somenet.com)
laptop.com
Server Name (e.g. www.somenet.com):
www.laptop.com
Administrator's Email Address (e.g. webmaster@somenet.com):
admin@laptop.com
Install Apache HTTP Server 2.0 programs and shortcuts for:
for All Users, on Port 80, as a Service -- Recommended.
only for the Current User, on Port 8080, when started Manually.
InstallShield
< Back
Next >
Cancel

9.2 General Configuration

Most of the configuration settings that relate to the operation of the web server are done via the httpd configuration file. This file is located in the confs directory, which is in the directory that the server was installed to. This file is a text based file, that is read by the server during loading.

An example of some of the configuration changes that are handled by this file, is the location of the web pages and the cgi programs. This allows the user to specify any directory that contains web pages that will be accessible for users. This configuration file is divided into three sections :

1. Global Environment
2. 'Main' server configuration
3. Virtual Hosts

The Global Environment allows settings such as the root directory where log file and configuration files are located. Also certain aspects of the operation of the web server can be changed via global environments, such as Timeout, Whether or not to allow persistent connections and maximum number of requests a server process serves. Aspects such as the number of request processed and the timeout are important for this project.

For the ATE remote access we want only one person changing the device settings at a time, using this global variable is not a very effective method of providing mutual exclusion. So for future implementation a better method of limiting access to one user at a time would be needed. Also the timeout property of the server may need to be changed, if the application applying the changes on the device takes to long the a time out may result. This could mean that a timeout may result when there is no problems on the server side, so increasing this timeout would help prevent this problem. But in order to not have the user waiting too long, so an approximation of the longest command processing time and a maximum round triptime for the request would need to be estimated.

The next section of the configuration file deals with the location of various files need by the server, including the HTML page that the server will provide access to. Along with this it also specifies the that access will be controlled, allowing or denying based on user names and passwords or IP addresses. This is where security settings can be enforced, through the selection of appropriate options.

Finally this last section allows the establishment of virtual hosts, which allows multiple domain/hostnames to exist on the one server. This maybe desirable if the server is to host web pages for different sites, such as a web hosting service would provide. In the case of this project there is no need to have multiple domains or hostnames, so this section will be left as is.

As mentioned earlier, there are many sources of apache web server configuration on the Internet. Hence the user is advised to search on the Internet for help regarding to the configuration of Apache Web Servers, if more detail is required. The site from which the Apache server is obtained, **www.apache.org** is recommended as a good starting point for such information.

9.3 Configuring Server

After the web server is installed, then all configurations are done via the httpd configuration file. This file is accessed and edited using a simple text editor, and contains code that look similar to HTML code. This file is read by the server application upon starting and specifies the operation of certain aspects of the server.

9.3.1 Controlling Access

For this project, there is the desire to provide a form of controlling access to this web site. Through the use of the httpd configuration file ,files created by the administrator and a file created by an application provide by the apache server, this facility can be provided.

The first stage in configuring controlled access is the creation of a password file, this is done using a program that comes with the apache server called *htpasswd*. This application is executed with three arguments, the first is the options that the user wishes to enable, secondly is the file that will store the user/password information created and last is the user that will be entered into the file. The basic operation of this application is as follows:

htpasswd -c /usr/local/apache/passwd/passwords username

The user will be prompted to enter the password, this will cause the creation of a

file in the specified directory. This file contains the users name and the encrypted version of the password, this is so later authentication can be achieved by comparing the encrypted version of the enter password with that in the file. Note that the -c flag is only use to create the file, if a user is to be added to an existing password file then this flag is submitted. This is very important as using the -c flag will cause the file to be overwritten.

Care must be taken in the placement of this file, as it contains password information that could be used to guess the actual password. For this reason this should be placed in a directory that the http server cannot access. Also the permissions of the file must be set to allow access by the web server user, hence deny access to other users.

After the password in created and placed in a directory, then the configuration files must be set to use this newly created password file. This is done by creating and placing a file in the directory that is password protected, this file must be give the name htaccess. The fields that must be entered into this file are now describe :

AuthType	Authentication type being used.
AuthName	The authentication realm or name.
AuthUserFile	The location of the password file.
AuthGroupFile	The location of the group file, if any.
Require	The requirement(s) which must be satisfied in order to grant admission.

The htaccess file created for the project's web server is as follows:

AuthName "ATE User Login : "
AuthType Basic
AuthUserFile "c:/Program Files/Apache Group/Apache2/conf/htpasswd"
AuthGroupFile /dev/null
require valid-user

From this it can be seen that the basic authentication is used to control the access to the devices, this could be and of the various authentication setting depending on the desired effect. The path to the password file is specified by the AuthUserFile line, and was placed in the conf directory which is only accessible by the web server. And the required field specifies that in order to be granted access the user must be have an entry in the password file, and the passwords must exist.

Finally after all files have been created and placed in their correct directories,

then the httpd configuration file must be edited to inform the server to use password access. This is done by editing *AllowOverride* option of the <Directory "C:/Program Files/Apache Group/Apache2/htdocs"> section, which specifies access to the web pages in this directory. The AuthConfig option is used to activate the password access, after all these steps are done then the web server must be restarted.

9.4 Adding Web Pages and CGI Programs

After the web server has been installed and configured as desired, then adding the contents of the web page is simply a case of placing the files in the correct directory. In the case of the html pages and cgi programs, this is the directory specified using the <Directory ... >.

The defaults for these fields are the htdocs and cgi-bin directories located in the directory where the web server was installed on the system. Once the files have been placed in their correct directories, then any links or references to these files in the HTML pages must be updated to reflect there current placement.

Chapter 10

System Test

The testing of this system was simply a matter of seeing weather it worked under certain circumstances, as there are no real other measurable performance aspects. The system must be test in a manner that would simulate it's normal operation if implemented in the real world. If operation under these circumstances then there is no reason why the system would not operate correctly through the Internet.

The ideal way of testing this system, would be to provide the remote access system to be accessible via the Internet. But this was not possible, due to difficulties imposed by the information technology services due the possible security faults. This is understandable as the windows 95 has many security faults, and is not recommended as a web server as specified by the apache web server developers.

So in order to test this system and eliminate any chances of compromising the security of the Universities network, the different components that a majority of the Internet used. The first element is over an ordinary Ethernet network, once success has been proven on this configuration, a router will be implemented. The router will allow the testing of how the system operates, when going from one network to another.

For the test of the system over an Ethernet, the PC's where given IP addresses 192.168.0.1 and 192.168.0.2 respectively.The second address was assigned to the PC running the remote access system created by this project. Gaining access to the system from the second PC, was simple a matter of entering 192.168.0.2\frames.html into the address bar of the web browser of the first PC.

Once performed the introduction web page loaded, and the function generators page was chosen. Entering data into the fields and pressing the submit button resulted in

the desired changes on the instrument, then another device was chosen and also proved successful. This means that the system operated successfully as predicted, under the first test circumstances.

The next test required the configuration of a router, in this case a laptop with an on-board network card and a PCMCIA network card. One of the Network Interface Card(NIC) was given an address of 192.168.0.1 and the other 192.168.2.1, and an entry was entered in the routing table of this PC so that information from one network to the other was passed to the correct interface device. Two PC's where connected to the laptop through the use of two network hubs, and each PC assigned an IP address that was from the same network of the NIC device of the laptop connected to the same hub. The system was tested using the ping command, and it was found that each host was reachable through the router.

Now the same test as previously used was duplicated, except the IP address was 192.168.0.2, and the PC being used was on a different network. The system was also proven successful under these circumstances. There was no noticeable delay, due to the router, but this was expected as on the Internet usually more than one router exists and the networks are processing more of a load.

So from these test, it is expected that the system will operate correctly over the Internet. Of course a much longer delay would be expected, but not enough to effect the system's performance. This is due to the fact that more routers would be traversed and the propagation delays caused by the communication media, the usual round trip time is around 200 ms. This would be noticeable, but the system only sends a small amount of data and would not be expect to cause the system to fail.

Chapter 11

Conclusion

At the completion of the thesis the system provides a small amount of functionality for each device, and web pages through which the interactions are performed. An Apache web server that hosted these web pages and provided password controlled access, was installed and configured. This was the major achievements of the project.

The web pages created to provide remote access to the devices could be used to provide access to the ATE Rack for external students. This would benefit student that would normally have to travel long distances to access these devices. Also assignments and practical assessments could be created using web pages and CGI programs, for students to complete remotely.

Also it is suggested that the systems that the ATE equipment is attached to is updated with more powerful computers. This will improve the security and performance of both the existing system and the system produced by this project. It will also help improve the development and testing of software developed using the methods outlined in the thesis.

The initial direction of this project was not as the author expect, with a client/server software development. The development of a web based system was emphasized by the Supervisor, as it solves some of the existing problems, so this was fully developed.

11.1 Suggested Further Development

Improvements to the current remote access system could include:

- The implementation of more functionality for each device.

- Development of a sequence of events for some test.
- Possibly the implementation of a graphical interface using Flash media web pages.
- Implement CGI programs using the VISA API library.

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